The Internet of Things IoT, a new ecosystem in an interconnected world: Bibliometric Analysis of 2009 - 2018

Héctor Javier Arciniegas Palomino
Faculty of electrical engineering
Universidad Santo Tomas, Bogotá, Cundinamarca, Colombia
Email- hjarcipalomino@hotmail.com

Sofia Orjuela
Department of Administrative Sciences
Universidad Francisco de Paula Santander, Cúcuta, Norte de Santander, Colombia
Email- sofiaorjuela@ufps.edu.co

Carlos Acevedo
Engineering Faculty
Universidad Francisco de Paula Santander, Cúcuta, Norte de Santander, Colombia
Email- carloshumbertoap@ufps.edu.co

Abstract- Taking into account that the wide development of technology has allowed the automation of objects and systems with which people interact, generating new ecosystems, challenges, and opportunities. Through the Web Of Science tool, the metadata information was obtained, which was analyzed and processed with the Histices program, obtaining the status of the research production generated by the different countries, institutions and authors, determining indicators such as the number of publications per country, language distribution, authorship, subject matter, among others, in short, the existing bibliometric statistics from 2009 to 2018. It is found that the total production of investigations between 2009 and 2018 was from 2005, of which China and the United States have the highest percentage, with 28.2% (566 articles) and 20% (405), respectively. Finally, since this topic is relatively recent and is in full growth and development, it is concluded that research production on the IoT topic in the coming years will have significant growth and it is expected that the increase of references to research already carried out, as well as the production of research documents will increase in subsequent years.

Keywords – Bibliometric, Big data, Cloud computing, Histcite, IoT Internet of things, Smart Cities, Smart Grid.

I. INTRODUCTION

The way we interact with objects, buildings [1], hospitals, houses, civil infrastructure, sports equipment [2], cars, medical equipment [3], household appliances, machinery, with our environment is changing and is partly due to the new models of connectivity generated by the incorporation in the objects of applications and functionalities of data and the Internet, which allows them a greater degree of relationship between things and people, things and environment and equally between things.

This technological revolution has been called the Internet of Things IoT, and many have not hesitated to call it the fourth industrial revolution [4] resembling the arrival of the steam engine because as in this stage of history a new technology has the potential to transform and modify people's lives, generating a change in the social, commercial, environmental and economic dynamics. This new technology has driven the emergence of new business models in society, changes in how services are provided, and is influencing various fields such as ecology, biology, medicine, agriculture [5], in practically all areas of knowledge that exist.

This new model of relations between objects, people, and their habitat has a number of benefits but jointly brings with it the same complications and challenges such as security, privacy [6], social [7], and legal regulations.

Because of its importance, progress, expansion and above all because of its high impact on society, it has attracted the attention of different areas of science (anthropological, legal, social, psychological, marketing, among others), generating in recent years a considerable volume of studies and publications.

The development of the Internet of Things technology, its scope, applicability and great potential to improve the life and comfort of people has generated a great interest in the scientific community which through publications of articles is exchanging studies, analysis and conclusions about the new scenarios that this technology entails; to identify the benefits and possible challenges that this technology brings. One of the recurring themes in the articles generated is the importance of coordinated development of knowledge on the subject, the economic and especially social impact that this would imply.

Existing studies and research focus on determining the capabilities of this technology, the opportunities and new social, economic, and commercial models that are created, and the problems and disadvantages that can be generated in terms of security and privacy [8]. Currently, there is no bibliometrics on the subject, so the main contribution of this work is to investigate and determine the statistics on the state of research on the subject of IoT. This study was conducted through the tool Hittites, which is a software that serves for the analysis of bibliometric information and visualization of scientific content available in Web of Science, allowing to obtain statistical data and conclusions presenting the results in tables and graphs.

II. MATERIALS AND METHODS

2.1 Methodology –

In this study, a search was made using the Web of Science (WoS) application through which the metadata of the articles and publications related to the IoT topic from 2009 to 2018 was obtained (the search was made on 10-03-2018). Through these metadata, information was obtained about the universe of existing articles and publications and specific data on the name of the article, author, year of publication, the institution where the research was carried out, the number of citations and references, and the dates on which they were published, among others. In the WoS tool, the equation search for internet+of+things was entered without any kind of filter, obtaining 2005 results (4 metadata files of 500 items and a file with five records).

Later through the software Histcite which is used for bibliometric analysis and tabulation of information that allows knowing data such as the amount of literature that has been generated on a field, in which countries, languages of publication, main authors, entities to which the authors belong, journals in which they were published, importance, etc.

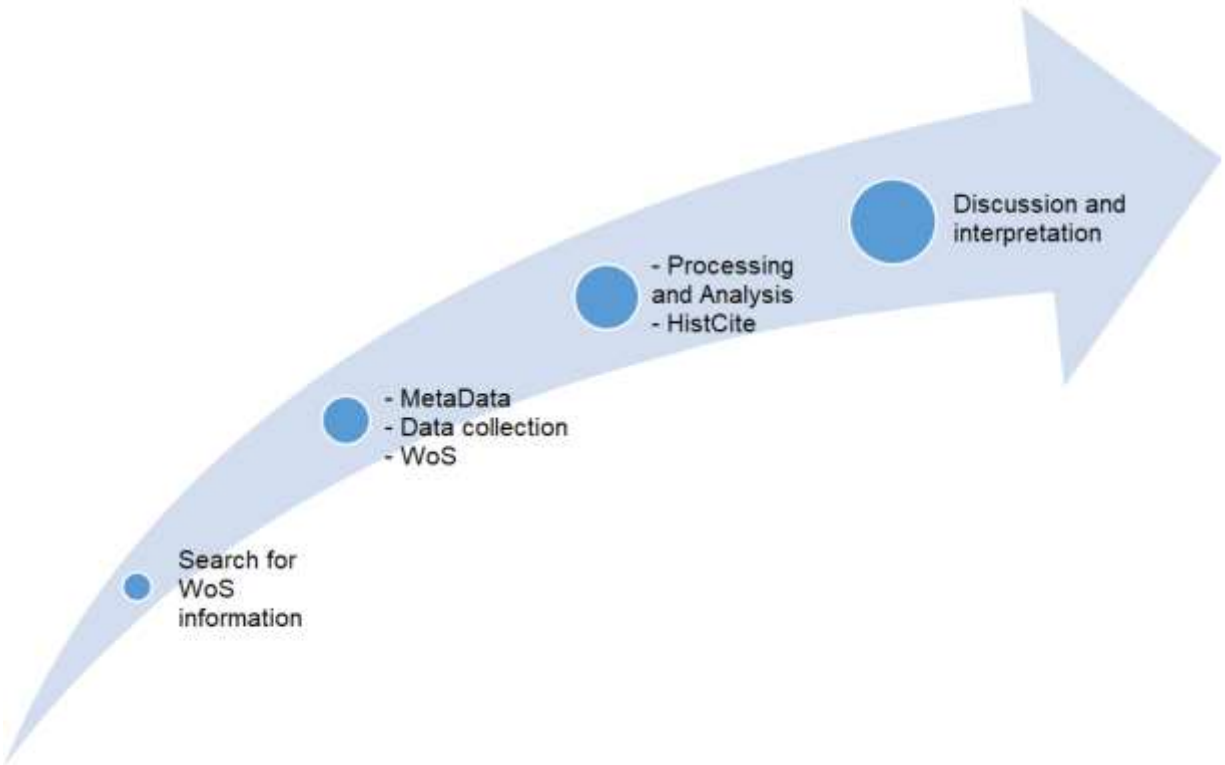

Figure 1. Methodology and Process - IoT Bibliometric Study

Using this information, the study and analysis of the records obtained were carried out, which were weighted through indicators such as LCS (Local Citation Score) and GCS (Global Citation Score) and tools such as Graph Maker. Figure 1 above shows the conceptual map of the process carried out.

III. Experiment and Result

The total production between the years 2009 to 2018 was of 2005 publications among articles, editorial material, magazines, news, books, etc. Figure 2 shows the annual distribution of total production.

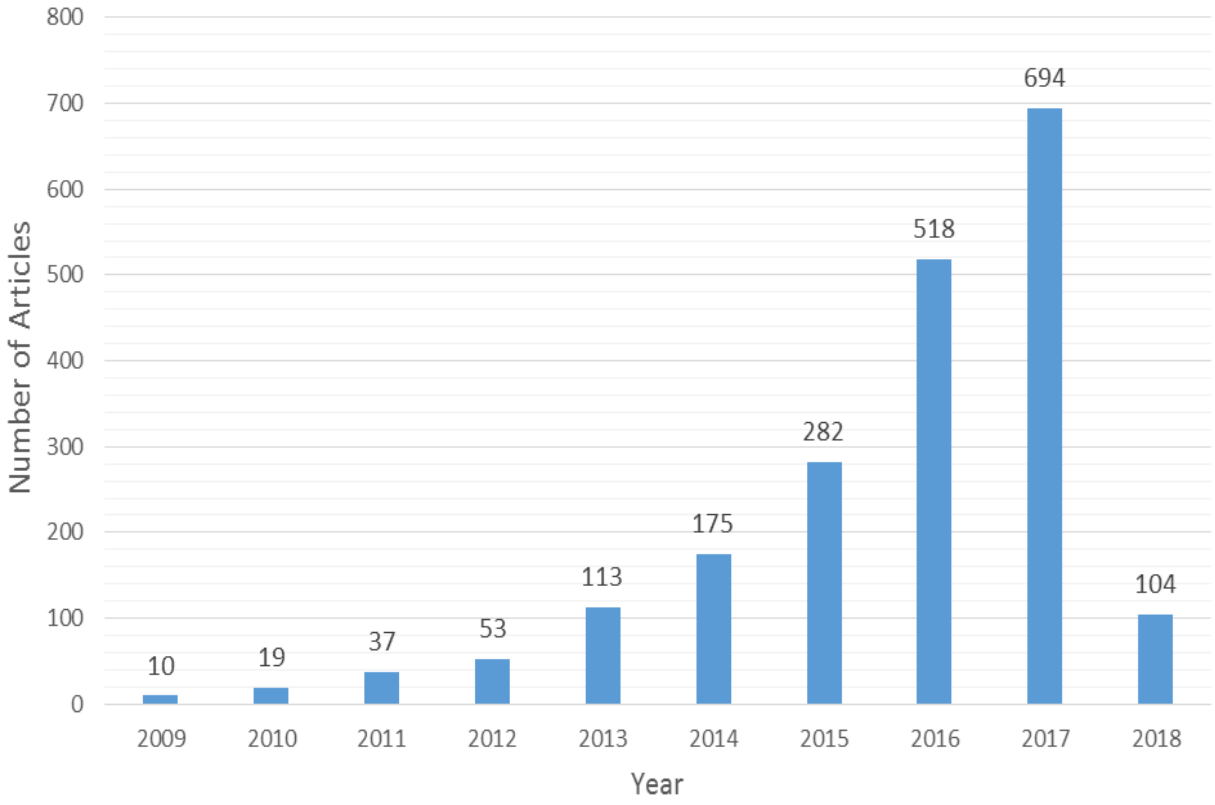

Figure 2. Number of articles per year from 2009 to 2018

The analysis of the information from Web of Science shows that since 2009 scientific articles on IoT have been published and that the production of these has been increasing exponentially between the years 2000-2017 in which the production of scientific articles was 10 and 694 respectively. This has been partly due to the exponential increase in bandwidths, the multiplication of the use of smartphones, commercial and advertising use of technologies, the growth and democratization of the Internet, efficient use of energy and above all by the need and eagerness of man to have information and applications that increase their comfort and convenience. From January 1, 2018, to March 10 of this year, the scientific production of articles was 194 publications, which projects for this year a final production of approximately 800 publications, an increase of 200 articles with respect to the previous year, equivalent to an increase of 25%.

The articles related to the topic of with IoT published and available in WoS were classified in 10 categories represented in 1608 magazine articles - 80.2%, 239 editorial materials - 11.92%, 70 review - 3.49%, 25 news reference - 1.25%; in these four categories are 95.61% of all publications. This distribution of research products can be seen in Figure 3.

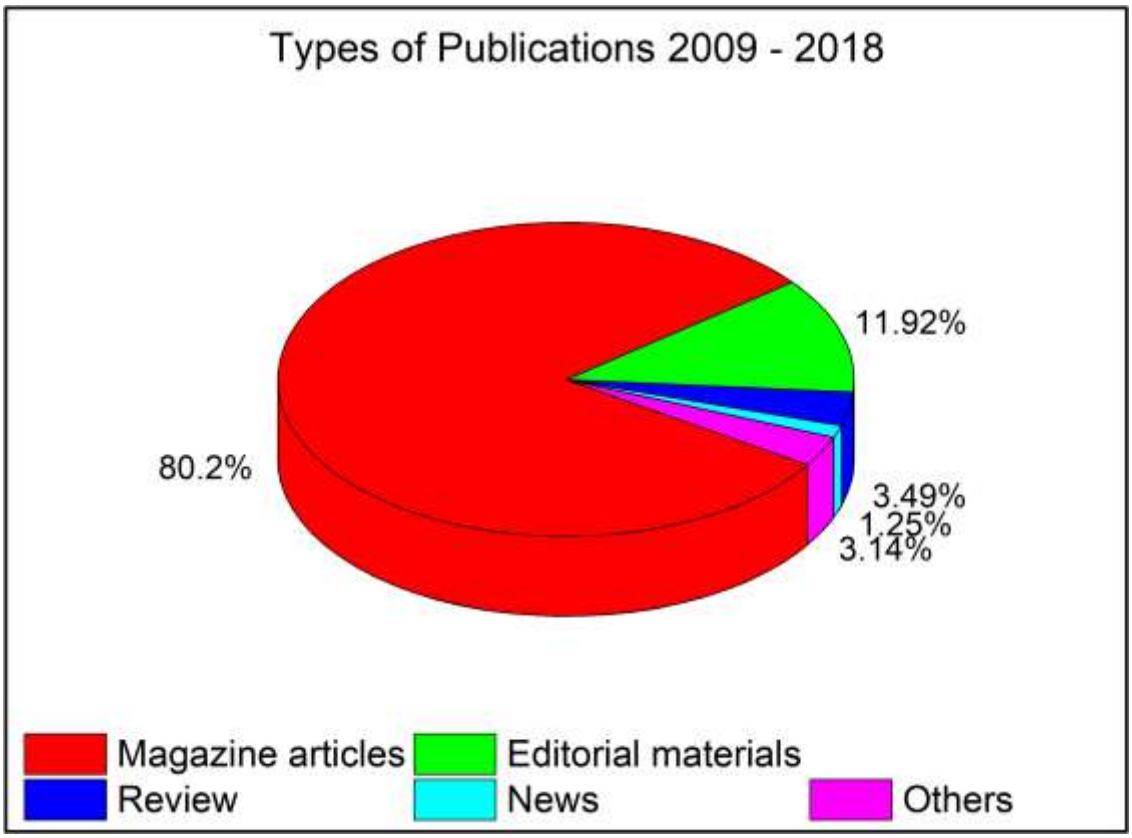

Figure 3. Categories IoT Publications 2009 - 2018

It can be seen that the number of publications has doubled annually since 2009. In 2010, the study The Internet of Things [9], is the article with the highest number of references. It presents an analysis of the challenges and opportunities that this new form of interconnection between people, things and the environment, the new businesses that would be created and their influence on the economic world, the benefits and negative impact on human relations in society and the challenges in security, integrity, and privacy that this new technology implies.

Table -1 TP Number of Publications, AU Number of Authors, NR Number of references per year, AU/TP, NR/TP Average number of Authors, references per article

Year	TP	AU	NR	AU/TP	NR/TP
2009	10	31	100	3.10	10
2010	19	53	729	2.79	38.4
2011	37	120	401	3.24	10.8
2012	53	176	429	3.32	8.1
2013	113	435	671	3.85	5.9
2014	175	560	866	3.20	4.9
2015	282	919	566	3.26	2.0
2016	518	1757	416	3.39	0.8
2017	694	2272	126	3.27	0.2
2018	104	415	6	3.99	0.1

Table 1 shows the peak signal to noise ratio of performance of our proposed method of watermarked image and original image with various watermark image, where our watermarked images peak signal to noise ratio has a better performance than others.

At the language level, the analysis concludes that since 2005, 98.4% of publications were in English, followed by Spanish 13 - 0.65% and German 8 - 0.4%. It is evident that almost 100% of the publications correspond to the English language, which is the dominant language of research in IoT, which is related to the fact that the journals with greater relevance in the subject are published in this language.

Table -2 List of articles by language - Local and Global References Recs Number of References, TLCS Total Local Citation Score, TGCS Total Global Citation Score.

Language	Recs	TLCS	TGCS
English	1973	4306	22792
Spanish	13	2	2
German	8	0	2
Portuguese	5	2	3
French	2	0	1
Russian	2	0	0
Chinese	1	0	0
Ukrainian	1	0	0

The analysis concludes that the average number of publications year after year has practically doubled, and likewise, there is a progressive increase in the number of references cited per year from 2009 to 2014; in the latter year the highest number of references to publications is recorded with a total of 866. Although the production of publications continues to increase at the same rate, the total number of references has not decreased, which indicates that the most significant scientific production has occurred in the five years following 2009.

In order to determine which countries have the greatest scientific creation, the analysis is carried out year by year (Figure 4), finding that the countries with the greatest production are China, followed by the United States, the United Kingdom, South Korea (the country has chosen to carry out the smart City pilot), Italy and Spain. Of the total production of publications at the country level, two countries in North America, 3 in South America, 5 in Asia, Europe, 1 in Central America and Oceania appear in the statistics.

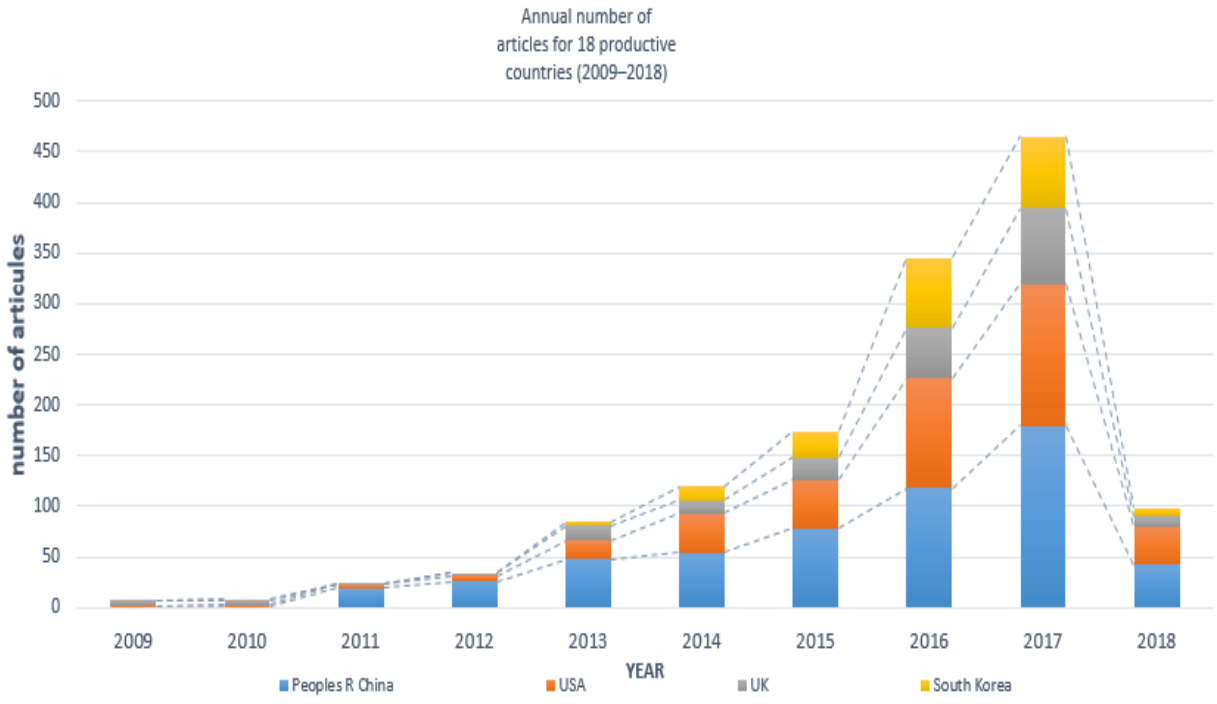

Figure 4. Annual number of articles for 18 productive countries (2009–2018)

The articles with the highest number of local citations are by Atzori L, Lera A, Morabito G, Gubbi J, Marusic S, Palaniswani M, and Xu LD (70 references).

Table -3 Production by country

#	Country	TP	TLCs	TGCs
1	Peoples R China	566	901	4952
2	USA	405	821	4963
3	UK	196	662	3185
4	South Korea	194	130	682
5	Italy	125	1130	6053
6	Spain	119	307	1422
7	Unknown	109	22	104
8	Australia	92	493	2887
9	France	92	154	742
10	India	92	87	433
11	Canada	83	136	630
12	Taiwan	74	111	461
13	Germany	73	274	1122
14	Sweden	69	134	635
15	Finland	44	107	584
16	Switzerland	43	143	819
17	Japan	41	57	230
18	Saudi Arabia	40	36	217

The top 10 of the entities with the greatest number of publications is shown in Figure 5, where we can see that the institution with the greatest number of research production belongs to China or South Korea.

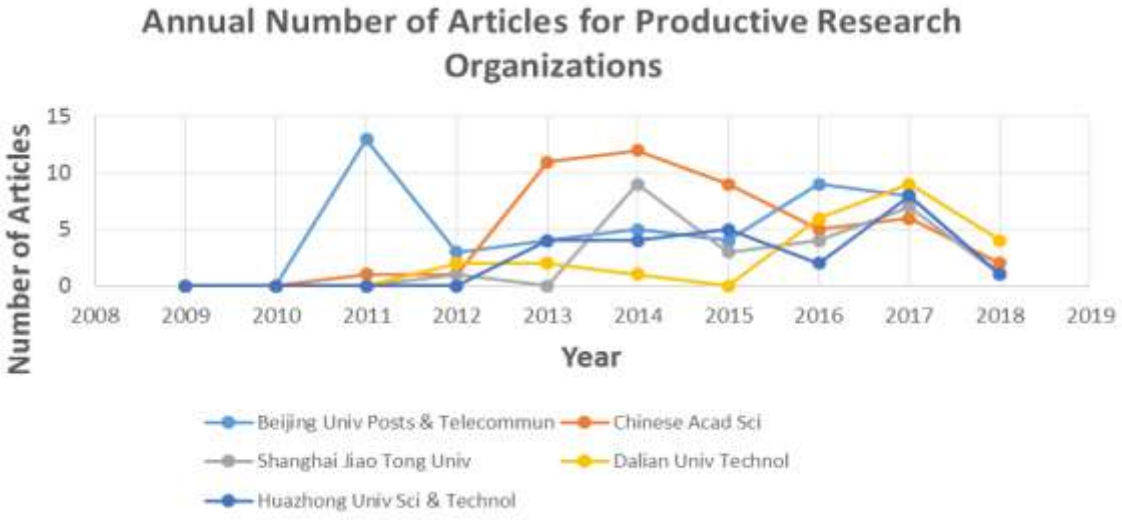

Figure 5. Annual Number of Articles for Productive Research Organizations

The University of Cagliari has produced 14 publications in the years 2010 (1), 2011 (1). 2012 (1), 2014 (3), 2015 (2), 2016 (3) y 2017 (3). It is evidenced as one of the most relevant entities since its scientific articles are within the ranking of the highest number of references with 449 LCS Local Citation Score with the article "The Internet of Things" Atzori L, Iera A, Morabito G followed by the article Internet of Things (IoT): A vision, architectural elements, and future directions Gubbi J, Buyya R, Marusic S, Palaniswami M, from the University of Melbourne with 229 LCS Local Citation Score.

Atzori et al. [9] presents different views of the Internet of Things paradigm and suggests the most relevant issues to be addressed in detail by the scientific community. Gubbi et al. [10] assess the technology that the IoT requires for its implementation, which must be supported and focused on the private and public cloud and the correlation between them. It sets out the technology platform, elements, trends, and expectations that the IO generates from the technological point of view as well as from the user's point of view.

One of the main challenges for the globalization of IoT is to standardize communication protocols so that hardware and software manufacturers can in the future interconnect under the same technological framework and

avoid the need to create additional interfaces for communication between different technology manufacturers. In this sense, the article Edge computing technologies for Internet of Things: a first of the author's Yuan Ai, Mugen Peng, Kecheng Zhang [11].

The top 20 of the most productive journals from (2009 to 2018) in the number of publications are shown below in Table -4.

Table -4 TP Number of Publications, Rank Position, Total LCS (Local Citation Score), % TCLs /Total Publications

Journal Name	TP	Percentage	Rank	TCLs	% TCLs/Total
IEEE INTERNET OF THE THINGS JOURNAL	108	5.4	1	303	7%
INTERNATIONAL JOURNAL OF DISTRIBUTED SENSOR NETWORKS	89	4.4	2	0	0%
SENSORS	76	3.8	3	53	1%
IEEE ACCESS	64	3.2	4	86	2%
IEEE COMMUNICATIONS MAGAZINE	57	2.8	5	185	4%
FUTURE GENERATION COMPUTER SYSTEMS - THE INTERNATIONAL JOURNAL OF eSCIENCE	46	2.3	6	289	7%
COMPUTER	33	1.6	7	117	3%
WIRELESS PERSONAL COMMUNICATIONS	33	1.6	8	112	3%
JOURNAL OF NETWORK AND COMPUTER APPLICATIONS	32	1.6	9	157	4%
IEEE CONSUMER ELECTRONICS MAGAZINE	31	1.5	10	7	0%
AD HOC NETWORKS	26	1.3	11	236	5%
COMPUTER & ELECTRICAL ENGINEERING	26	1.3	12	59	1%
PERSONAL AND UBIQUITOUS COMPUTING	26	1.3	13	67	2%
CHINA COMMUNICATIONS	23	1.1	14	16	0%
COMPUTER NETWORKS	23	1.1	15	635	15%
MOBILE INFORMATION SYSTEMS	23	1.1	16	13	0%
IEEE SENSOR JOURNAL	20	1.0	17	68	2%
IEEE WIRELESS COMMUNICATIONS	19	0.9	18	145	3%
INTERNATIONAL JOURNAL OF ONLINE ENGINEERING	19	0.9	19	1	0%
IEEE TRANSACTIONS ON INDUSTRIAL INFORMATICS	18	0.9	20	193	4%

It is evident that 64% of the citations of the publications correspond to the Top 20 of the journals registered in the bibliometric study, highlighting the IEEE journal.

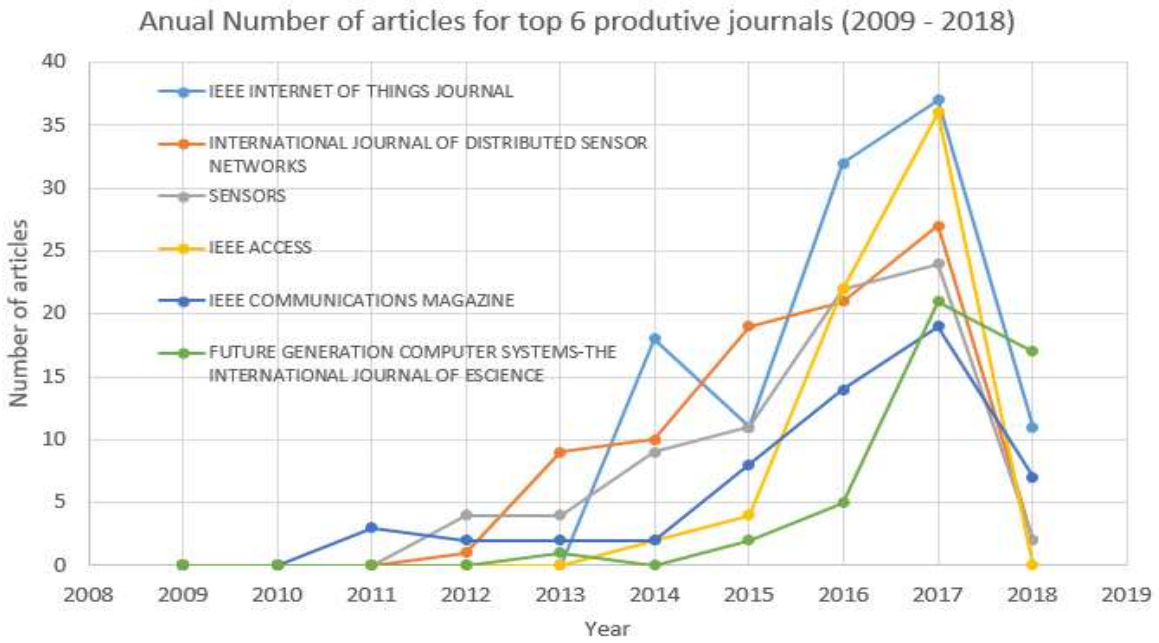

Figure 6. Annual Number of articles for top 6 productive journals (2009 – 2018)

As shown in Table -5, the entity or research center from which the publications with the greatest number of references originated are COMPUTER NETWORKS with two articles within the TOP 10 and has the most referenced publication. The IEEE appears as the institute with more publications within this TOP 21, with four publications being the most referenced the [8].

Table -5 Top 10 Articles - Citations per year. (2009 – 2018).

Title (Autor)	Journal (Published Time)	Citations	Citations Per Year
The Internet of Things: A survey. 25 Atzori L, Lera A, Morabito G	COMPUTER NETWORKS. 2010 OCT 28; 54 (15): 2787 - 2805	449	49.89
Internet of Things (IoT): A vision, architectural elements, and future directions. 192 Gubbi J, Buyya R, MArusic S, Palaniswami M	FUTURE GENERATION COMPUTER SYSTEMS – THE INTERNATIONAL JOURNAL OF eSCIENCE. 2013 SEP; 29 (7): 1645 – 1660	229	38.17
Internet of Things: Vision, applications, and research challenges. 103 Miorandi D, Sicari S, De Pellegini F, Chlamtac I	AD HOC NETWORKS. 2012 SEP; 10 (7): 1497 - 1516	154	22.00
Smart Objects as Buildings Blocks for the Internet of Things. 13 Kortuem G, Kawsar F, Fitton D, Sundramoorthy V	IEEE INTERNET COMPUTING. 2010 JAN – FEB; 14 (1): 44 - 51	76	8.44
Context Aware Computing for the Internet of Things: A survey. 237 Perera C, Zaslavsky A, Christen P, Georgakopoulos D	IEEE COMMUNICATIONS SURVEYS AND TUTORIALS. 2014; 16 (1): 414 - 454	73	14.60
Internet of Things in Industries: A survey. 383 Xu LD, He W, Li SC	IEEE TRANSACTIONS ON INDUSTRIAL INFORMATICS. 2014 NOV; 10 (4): 2233 - 2243	70	14.00
Internet of Things for Smart Cities. 277 Zanella A, Bui N, Castellani A, Vangelista L, zorzi M	IEEE INTERNET OF THINGS JOURNAL. 2014 FEB; 1 (1): 22 -32	57	11.40
From Today Intranet of Things to a Future Internet of Things: A Wireless – And Mobility – Related View 28 Zorzi M, Gluhak A, Lange S, Bassi A.	IEEE WIRELESS COMMUNICATIONS. 2010 DEC; 17 (6): 44 - 51	55	6.11
The Social Internet of Things (SIoT) – When social networks meet the Internet of Things: Concept, architecture, and network characterization. 115 Atzori L, Lera A, Morabito G, Nitti M	COMPUTER NETWORKS. 2012 NOV 14; 56 (16): 3594 - 3608	55	7.86
Interacting with the SOA-Based Internet of Things: Discovery, Query, Selection, and On-Demand Provisioning of Web Services. 20 Guinard D, Trifa V, Karnouskos S, Spiess P, Savio D	IEEE TRANSACTIONS ON SERVICES COMPUTING. 2010 JUL – SEP; 3 (3): 223 - 235	54	6.00

The results show that the most frequent words in the titles of the articles are Internet, Things, Based, data, and smart Figure 7. The Internet of Things IoT aims at the fact that in the future objects can communicate with people and also interconnect between them generating a network that is similar to the neural networks handled by human beings (smart things -Smart cities - Smart Grid) in which some systems will integrate with others forming ecosystems that can make decisions autonomously under certain conditions or scenarios.

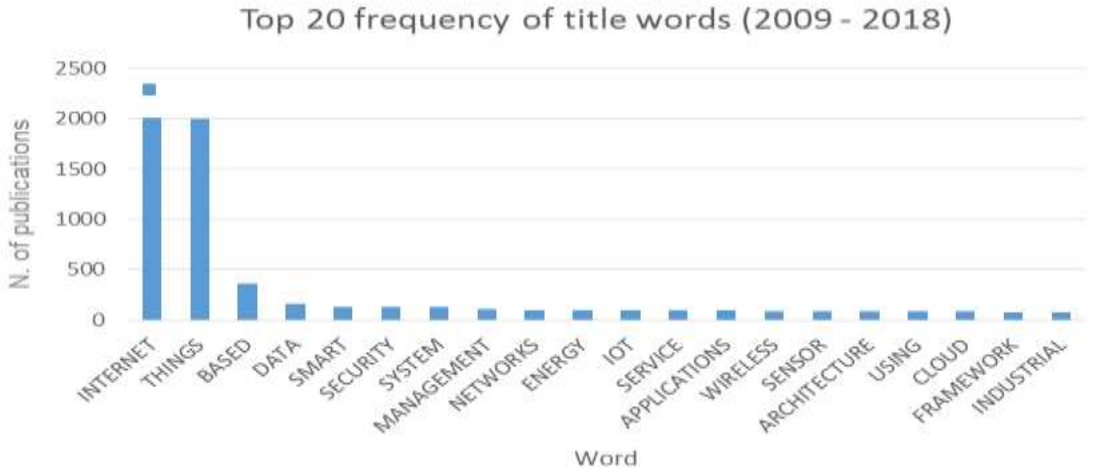

Figure 7. Top 20-word frequency in article titles

The chronological graph is made in the Histcite tool, where the quotations for the IoT items are displayed, Figure 8. In this graph, the number of articles cited (Nodes in the Figure) can be determined, and the arrows are directed to the documents cited.

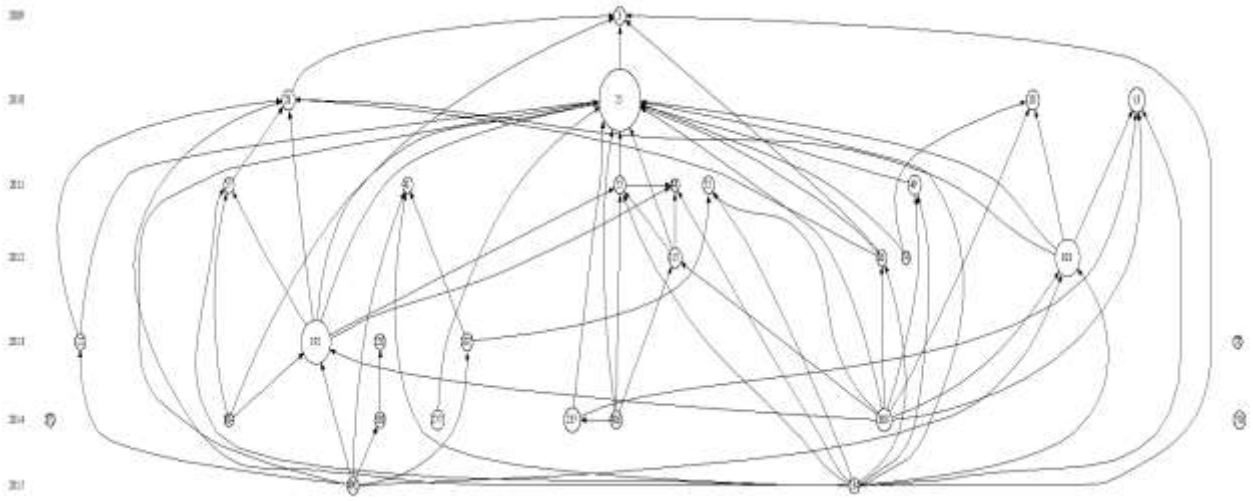

Figure 8. Chronological analysis of articles and citations

The chronological diagram shows a total of 30 nodes and 50 links (Nodes: 30, Links: 67). The table relates the most referenced authors with their corresponding LCS value. LCS, top 30; Min: 26, Max: 449 (LCS scaled).

Table -6 Research articles and references interconnection

	Interconnection of research articles and references	LCS	GCS
3	Welbourne E, 2009, IEEE INTERNET COMPUT, V13, P48	46	232
13	Kortuem G, 2010, IEEE INTERNET COMPUT, V14, P44	76	422
20	Guinard D, 2010, IEEE T SERV COMPUT, V3, P223	54	247
25	Atzori L, 2010, COMPUT NETW, V54, P2787	449	2849
28	Zorzi M, 2010, IEEE WIREL COMMUN, V17, P44	55	168
41	Roman R, 2011, COMPUT ELECTR ENG, V37, P147	31	90
44	Ning HS, 2011, IEEE COMMUN LETT, V15, P461	27	76
49	Bandyopadhyay D, 2011, WIRELESS PERS COMMUN, V58, P49	53	233
52	Roman R, 2011, COMPUTER, V44, P51	47	158
55	Atzori L, 2011, IEEE COMMUN LETT, V15, P1193	39	113
57	Gluhak A, 2011, IEEE COMMUN MAG, V49, P58	33	117
74	Barnaghi P, 2012, INT J SEMANT WEB INF, V8, P1	28	122
86	Domingo MC, 2012, J NETW COMPUT APPL, V35, P584	33	130
103	Miorandi D, 2012, AD HOC NETW, V10, P1497	154	707
115	Atzori L, 2012, COMPUT NETW, V56, P3594	55	203
122	Palattella MR, 2013, IEEE COMMUN SURV TUT, V15, P1389	31	141
170	Vlacheas P, 2013, IEEE COMMUN MAG, V51, P102	27	94
187	Roman R, 2013, COMPUT NETW, V57, P2266	43	166
192	Gubbi J, 2013, FUTURE GENER COMP SY, V29, P1645	229	1455
228	Sheng ZG, 2013, IEEE WIREL COMMUN, V20, P91	32	187
237	Perera C, 2014, IEEE COMMUN SURV TUT, V16, P414	73	417
272	Perera C, 2014, T EMERG TELECOMMUN T, V25, P81	28	171
276	Stankovic JA, 2014, IEEE INTERNET THINGS, V1, P3	47	253
277	Zanella A, 2014, IEEE INTERNET THINGS, V1, P22	57	504
304	Jin J, 2014, IEEE INTERNET THINGS, V1, P112	26	154
338	Yan Z, 2014, J NETW COMPUT APPL, V42, P120	35	194
383	Xu LD, 2014, IEEE T IND INFORM, V10, P2233	70	364
406	Borgia E, 2014, COMPUT COMMUN, V54, P1	44	142
490	Sicari S, 2015, COMPUT NETW, V76, P146	45	152
534	Whitmore A, 2015, INFORM SYST FRONT, V17, P261	30	132

IV.CONCLUSION

Research on the Internet of Things IoT has steadily increased annually since 2009, covering important areas such as psychology, economics, legal, social, etc.

Based on the trend of growth in the number of investigations, as well as the progress in technology and the rate of growth thereof, it is expected that there will be even greater growth in research and, therefore, in publications in the coming years. At present, there are 80 countries that have contributed with research and publications, being the most relevant countries those of China, USA, UK, South Korea, Italy and Spain, countries that in the next years are expected to remain in the TOP 10 of the countries that contribute more in the research of this topic.

According to the study, the IEEE journal had the most publications with the highest number of references or citations. Being a journal of the Institute of Electrical and Electronic Engineering which is a worldwide association of engineers dedicated to the standardization and development of areas in the areas of technology is expected to continue to be one of the institutes generating research papers that contribute significantly to the state of the art of the Internet of Things IoT.

The development of this technology will continue in a growing development aligned with the development of society and the need to have more interconnected, more efficient, and more communicated.

REFERENCES

[1] Z. Huang, K.-J. Lin, B.-L. Tsai, S. Yan, and C.-S. Shih, "Building edge intelligence for online activity recognition in service-oriented IoT systems," *Futur. Gener. Comput. Syst.*, vol. 87, pp. 557–567, 2018.
[2] B. Yong *et al.*, "IoT-based intelligent fitness system," *J. Parallel Distrib. Comput.*, vol. 118, pp. 14–21, 2018.
[3] S. Darwish, I. Nouretdinov, and S. D. Wolthusen, "Towards Composable Threat Assessment for Medical IoT (MIoT)," *Procedia Comput. Sci.*, vol. 113, pp. 627–632, 2017.
[4] D. Mourtzis, E. Vlachou, and N. Milas, "Industrial Big Data as a Result of IoT Adoption in Manufacturing," *Procedia CIRP*, vol. 55, pp. 290–295, 2016.
[5] K. Foughali, K. Fathallah, and A. Frihida, "Using Cloud IOT for disease prevention in precision agriculture," *Procedia Comput. Sci.*, vol. 130, pp. 575–582, 2018.
[6] R. Roman, J. Zhou, and J. Lopez, "On the features and challenges of security and privacy in distributed internet of things," *Comput. Networks*, vol. 57, no. 10, pp. 2266–2279, 2013.
[7] L. Atzori, A. Iera, G. Morabito, and M. Nitti, "The Social Internet of Things (SIoT) – When social networks meet the Internet of Things: Concept, architecture and network characterization," *Comput. Networks*, vol. 56, no. 16, pp. 3594–3608, 2012.
[8] D. Miorandi, S. Sicari, F. De Pellegrini, and I. Chlamtac, "Internet of things: Vision, applications and research challenges," *Ad Hoc Networks*, vol. 10, no. 7, pp. 1497–1516, 2012.
[9] L. Atzori, A. Iera, and G. Morabito, "The Internet of Things: A survey," *Comput. Networks*, vol. 54, no. 15, pp. 2787–2805, 2010.
[10] J. Gubbi, R. Buyya, S. Marusic, and M. Palaniswami, "Internet of Things (IoT): A vision, architectural elements, and future directions," *Futur. Gener. Comput. Syst.*, vol. 29, no. 7, pp. 1645–1660, 2013.
[11] Y. Ai, M. Peng, and K. Zhang, "Edge computing technologies for Internet of Things: a primer," *Digit. Commun. Networks*, vol. 4, no. 2, pp. 77–86, 2018.